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Author(s)	TABUCHI, Atsushi
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Evaluation of Shear performance of Earth wall in the Japanese traditional timber structure

Atsushi TABUCHI

Laboratory of Structural Function, RISH, Kyoto University

In this research, it was found out that shear performance of earth wall in Japanese traditional timber structure, and developed the way to evaluate the performance by using material constant.

(1)Evaluation of shear performance as material constant

An earth wall was constructed from mud, rice straw and bamboo. After mud was mixed with rice straw, it was molded on bamboo lath. In order to find out a behavior of bamboo lath in mud, interaction between mud and rice straw was focused on, and small size specimens which have 300 mm length, 300mm width and 70mm thickness were proved by lateral shear test. Fig.1 shows experimental set-up and dimension of a specimen. It was found out that shear stiffness was 4.0 N/mm^2.

And then a behavior and embedment of a bamboo as a lath of earth wall was evaluated by a theory of a beam on elastic foundation. In fact, it was assumed that a bamboo lath was a beam and mud was elastic foundation. This analysis showed that maximum deformation angle of bamboo lath was about 1/150 rad and this deformation angle could be ignored because of smaller value than a deformation of Nuki beam and other timber frames. As a result, it was found out that earth wall was integrated material with bamboo lath, a shear stiffness evaluated from above experiment was propriety.

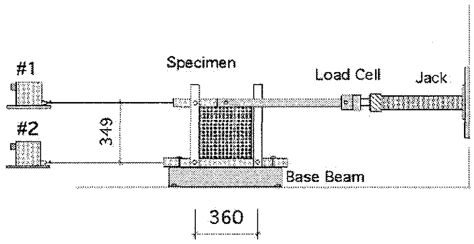

Fig 1: Experimental set up and dimensions

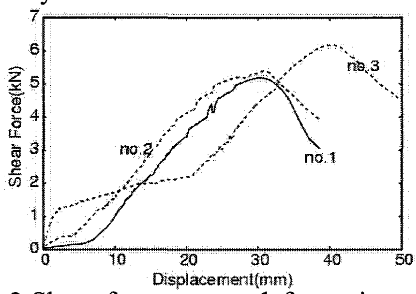

Fig2:Shear force versus deformation angle of element experiment

(2)Full scale lateral shear test of earth wall in case of Kyomachiya (town house of Kyoto) style

Figs 3 and 4 show experimental set-up and dimension of specimens. Keeping the typical module of Kyomachiya with 60mm thickness and 980mm column-to-column, Type-A had 1820mm column-to-column span and Type-B had 980mm width. Height of each specimen was 2500mm. These specimens were loaded on its beam laterally with tie rods in case of rocking rotation.

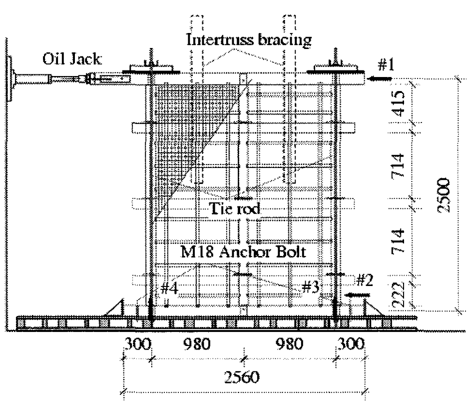

Fig3:Experimental set up and dimensions of type-A

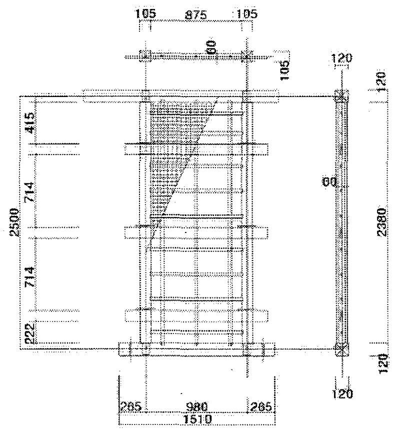

Fig4: Dimensions of type-B

Shear stress versus shear deformation angle curve is shown in Figs.5 and 6. These figures show that a maximum shear force of type-A was about 15kN and that of type-B was about 8.3kN. In addition, it was found out that shear stiffness of each type was similar. And the structural model of a timber frame was constructed using the theory of a beam on elastic foundation. According to this newly formulated model, the stiffness and strength of an earth wall in Kyomachiya can be evaluated simply.

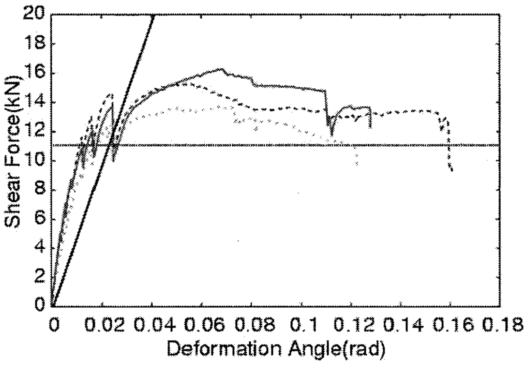

Fig5:Shear force versus deformation angle of type-A and results of physical model

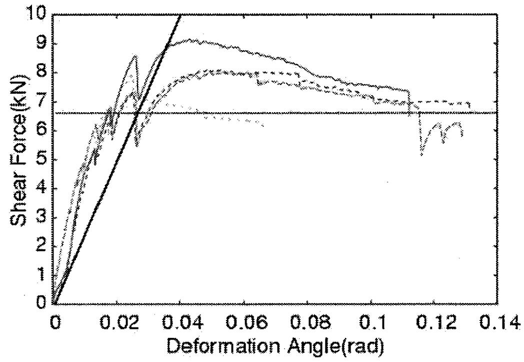

Fig6:Shear force versus deformation angle of type-B and results of physical model

(3)Lateral shear performance of kokabe-wall

Kokabe-wall, which has a opening under itself, is not anticipated as a shear wall (Fig.7). However, it has some strength. In that reason, timber frames with kokabe-wall were tested by lateral shear loaded. As the result, it was found out that the maximum load of a timber frame with kokabe-wall was about 1.9 times larger compared to those without it. The stiffness of timber frame alone was evaluated by using the physical characteristic model of embedment at Hozo (tenon) and Nuki-joint. Further, the stiffness of the kokabe-wall alone was evaluated by using shear stiffness and young modulus of earth wall. Final stiffness of the total structure was achieved by combining the two stiffness.

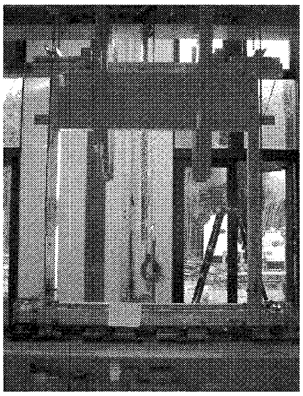

Fig7:Timber frame with kokabe wall

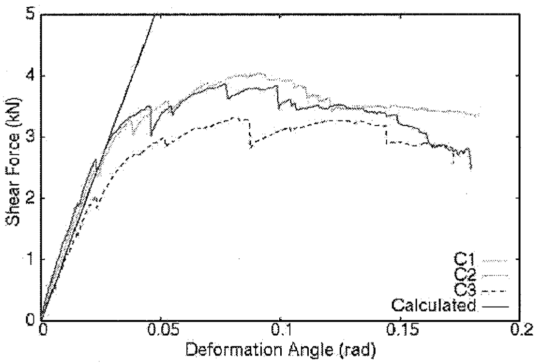

Fig8:Shear force versus deformation angle and calculated shear stiffness

(4)Conclusion

- Material testing was developed to evaluate a material constant of earth wall.
- It was found out that an embedment of bamboo lath to mud on earth wall could be ignored.
- It was proposed the newly formulated model by which a stiffness and strength of earth wall in Kyomachiya style could be evaluated simply.
- A stiffness of kokabe wall could be evaluated by using shear stiffness of earth wall and young modulus of timber.